Introduction to the Path Coordination Guide for the 70/80 GHz Millimeter-Wave Band

February 27, 2004

WCA 60+ GHz: 70/80GHz Interference Calculation Subcommittee

Document Approval Process

- **WCA 60+ GHz committee to approve the draft (with modifications as appropriate)**
- **WCA Engineering committee to approve draft**
- **PCG then to be posted on WCA website?**

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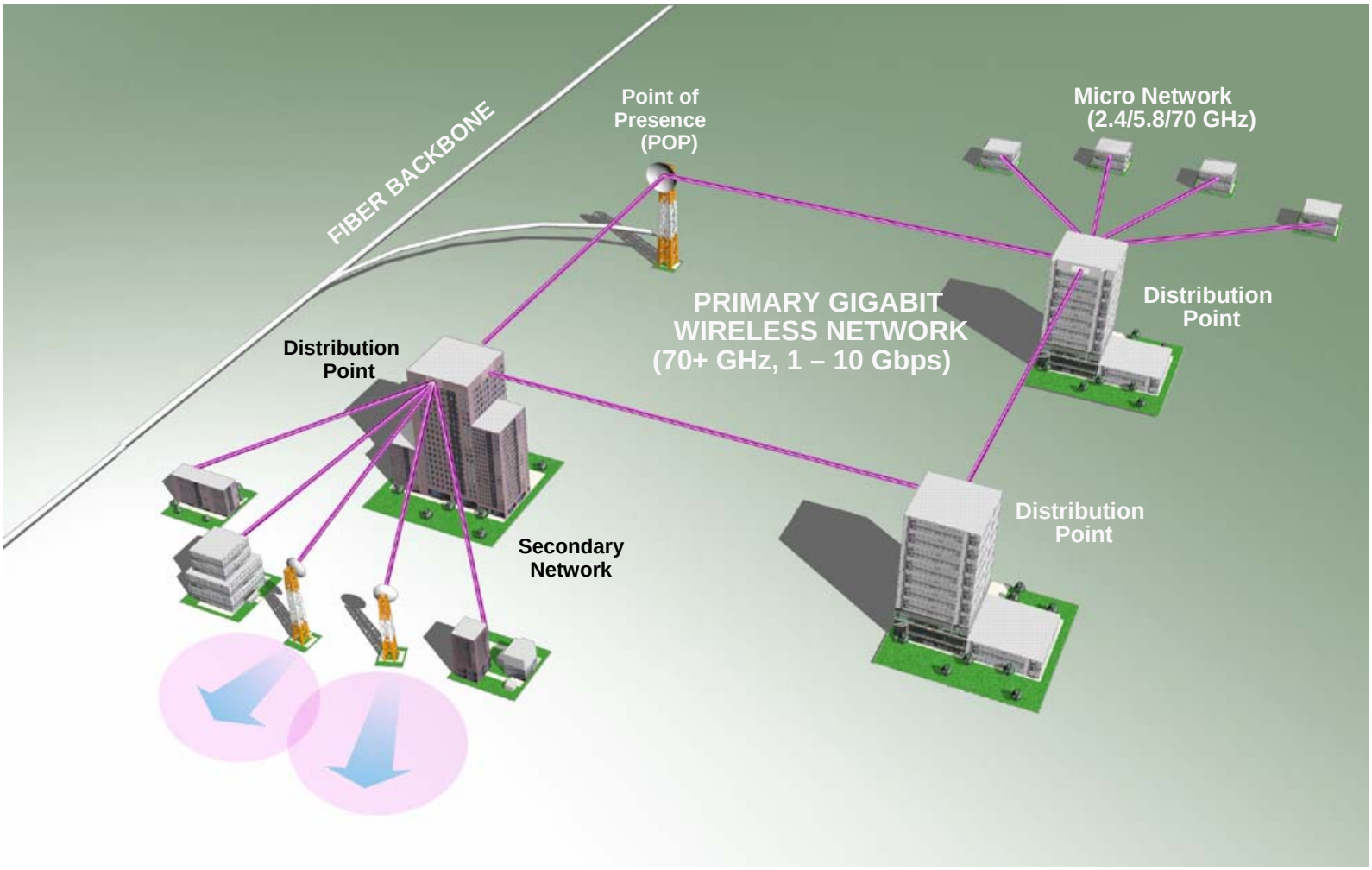
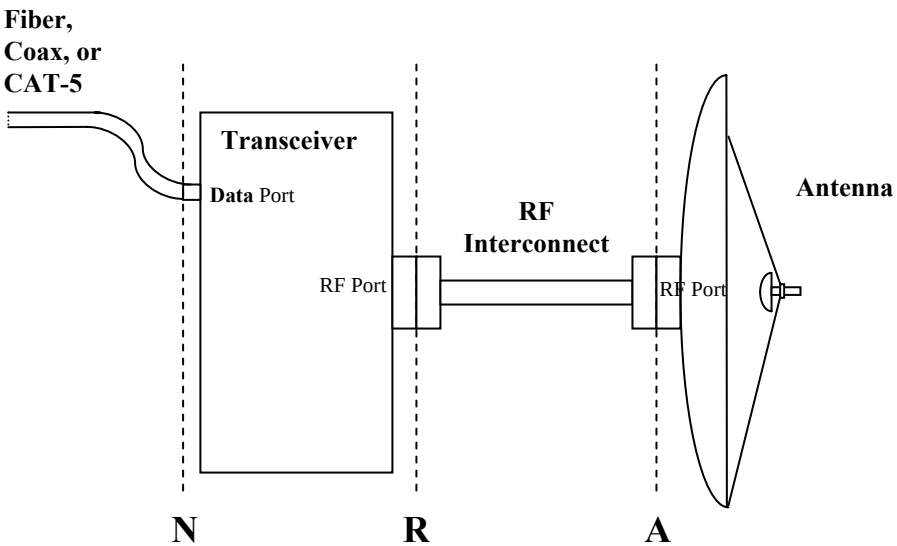
Document Overview

- **Document Outline**
  - **Section 1: introduction**
  - **Section 2: system overview and typical scenarios where interference can occur**
  - **Section 3: propagation models, building/tower issues, ATPC behavior**
  - **Section 4: path coordination process**
- **Issue: synchronizing with expected changes to FCC's R&O**
- **What's postponed for future revisions**
  - **Coordination for the 92-95 GHz band**
  - **Coordination with systems employing analog modulation**
  - **RAS coordination pending NTIA publication (note this is section 5 of the PCG)**

System Overview

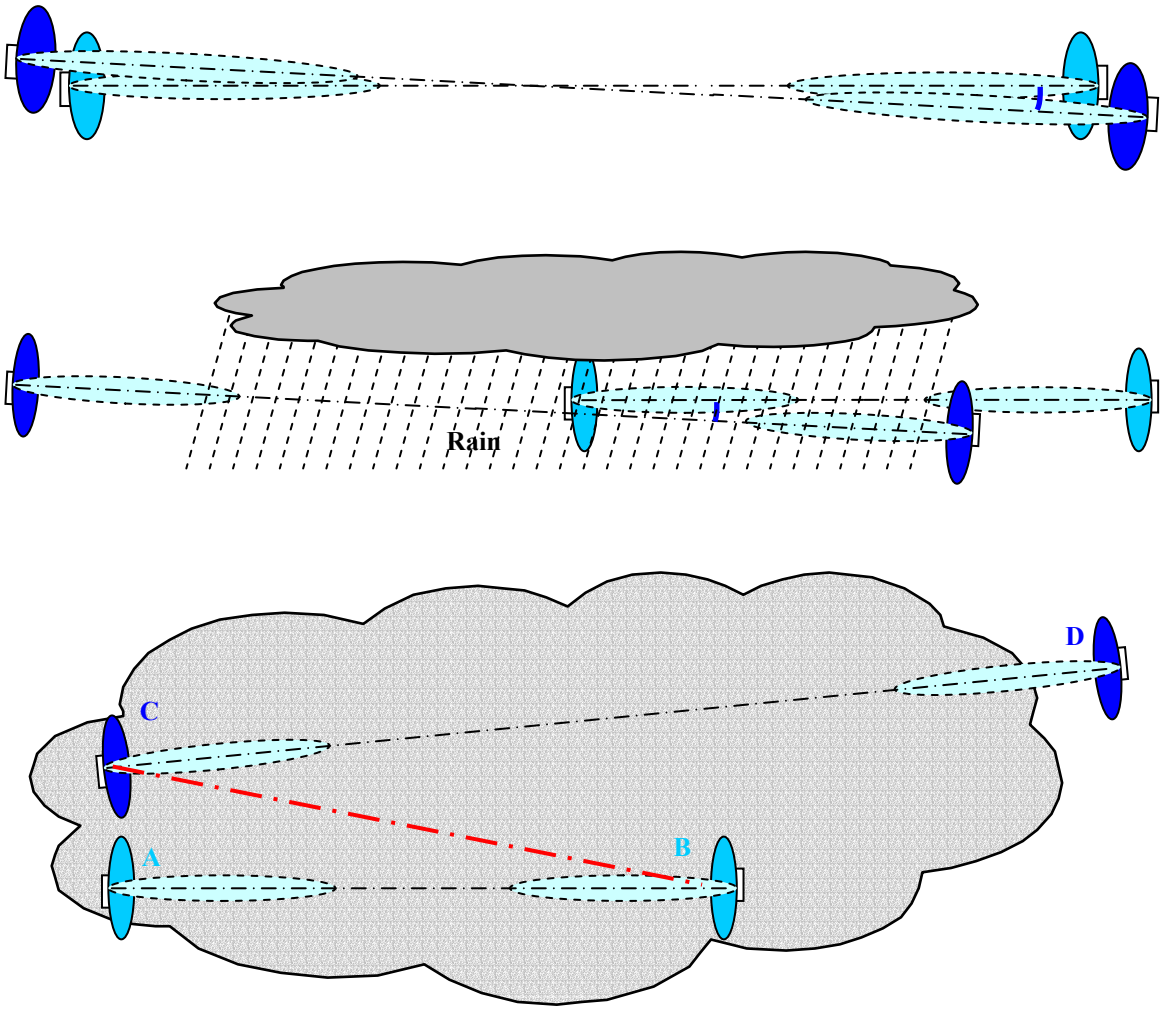


Reference Planes



- **A (antenna) port: facilitates different antennas with the same transceiver**
- **R (radio) port: facilitates deployments with transceiver separated from antenna with associated feedline losses**
- **N (network) port: this interface is not specified**

Interference Scenarios

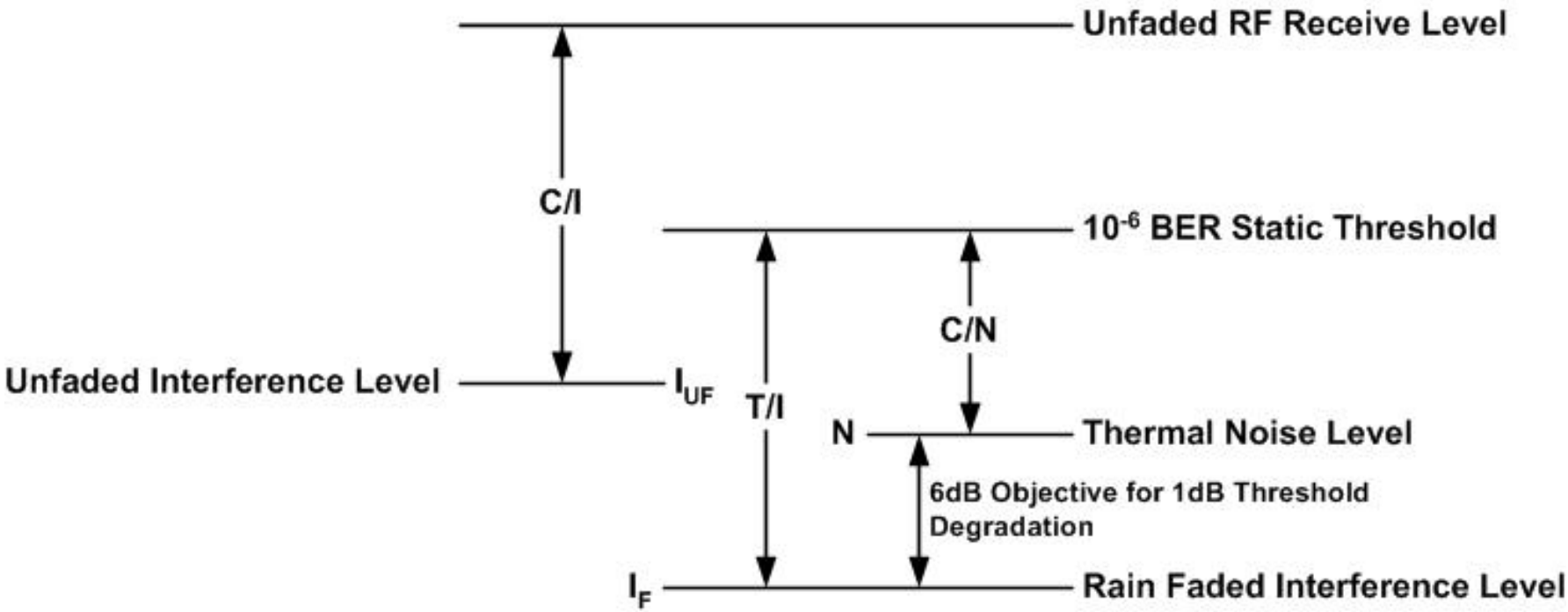


Interference due to nearly collinear main beams

Rain fading is correlated between desired and interfering paths

Hub-and-spoke interference is worse on short paths during rainfall

Interference Levels



- **Interference protection equivalent in value to T/I is provided over the entire received signal level range**

Path Availability and Interference Margin

- **Path availability is proportional to the rain fade margin engineered on the link**
  - **Function of the link budget**
  - **TID (see below) typically has minor impact on availability**
- **The rain fade margin is recommended to be reduced by 4dB—in the PCG this is referred to as total interference degradation (TID)**
  - **1dB for single-exposure interference degradation (interference degrades C/N by this amount)**
  - **3dB for multiple exposure allowance (MEA)**

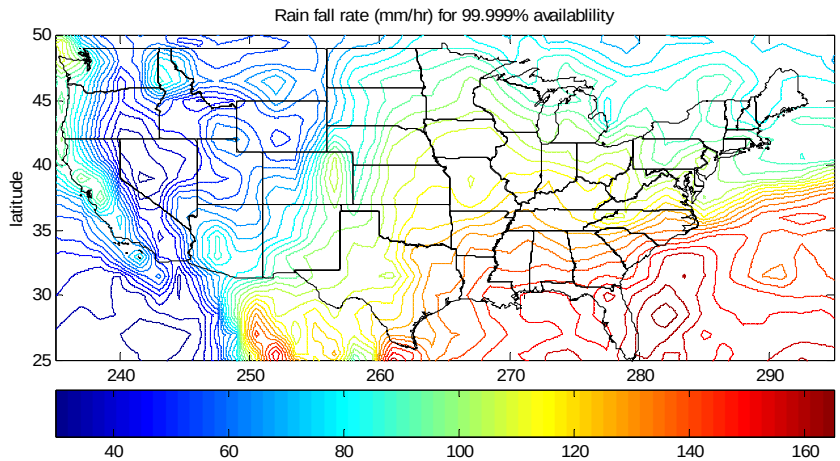
Propagation

Propagation Overview

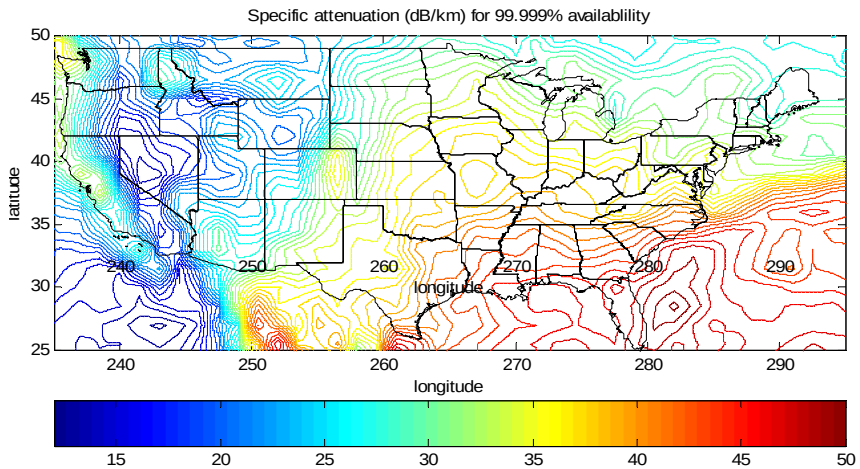
- **Free Space Path Loss** $L_{fs} = -20\log\left(\lambda / 4\pi D\right)$
- **Atmospheric Absorption Losses** $L_{atm} \sim 0.4\ \text{dB/km}$
- **Precipitation Losses** $L_{rain} = 0.885R^{0.785}\ (73.5), 0.985R^{0.765}\ (83.5)$
- **Precipitation-Induced Depolarization** $XPD = 15 + 26\log f - 20\log\left|L_{rain}\right| - 40\log\left(\cos\theta_{el}\right)$
- **Fog Loss** $L_{fog} = 4.4e^{-0.03T}\rho \le 2\ \text{dB/km}$
- **Snow and Ice Loss** $L_{ice}(R) \approx 0.05L_{rain}(R)$
- **RF Backscatter from Precipitation** $P_{bs} / P_t = 2.5\times10^{-7} R^{0.58}$
- **Over-the-Horizon and Building Obstruction Losses**

Rainfall and Rain Cell Models

- **Rain Model:**
  - ITU-R P.837-4



- **Rain Attenuation:**
  - $L_{73.5} = 0.885R^{0.785}$
  - $L_{83.5} = 0.985R^{0.765}$

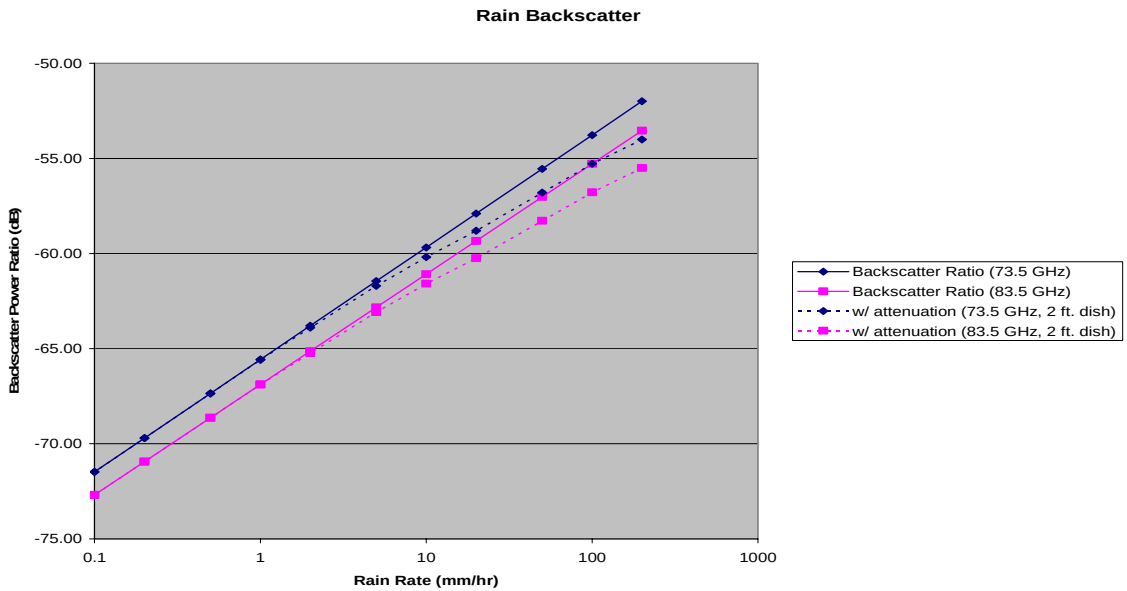


- **Rain Cell Model:**
  - ITU-R P.452-10

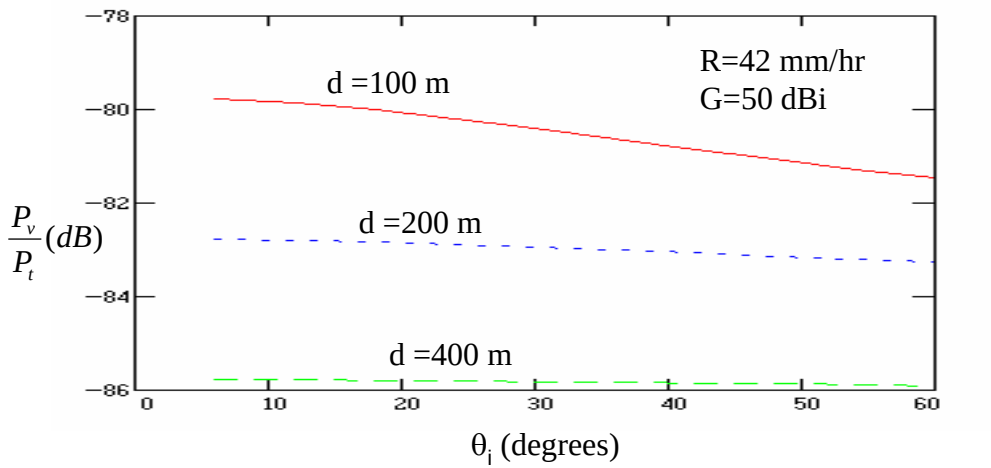
$d_c = 3.3R^{-0.08}$ km (plus debris field)

Rain Backscatter and Rain-Scattered Interference

- **Monostatic Case**
  - **Self-Interference**
  - **Co-sited Link Geometries**



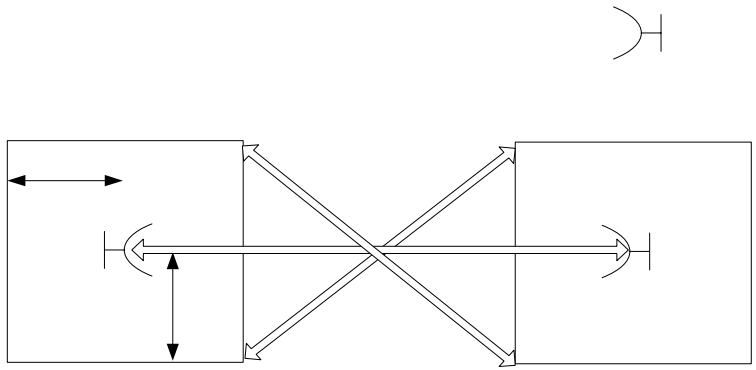
- **Bistatic Case**
  - **vs. separation, pointing angles, antenna gain**

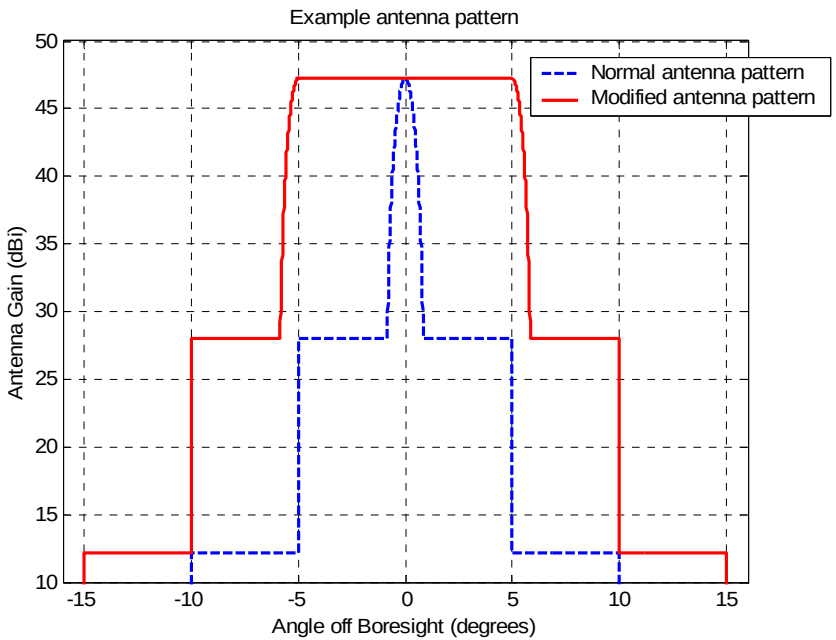


Over-the-Horizon Loss

- **NSMA (Longley-Rice) model**
  - **Model describes diffraction from single and multiple knife edges and rounded obstacles, troposcatter**
    - ✓ **Will require modification for application to E-band; mods specified future version of the PCG**
    - ✓ **For now, we take the conservative position that attenuation will be at least as great as that modeled by a single knife-edge and therefore adopt a single knife-edge model**
  - **Based on path profile from digitized terrain database**
- **Primary application for clearing interference within large coordination radius around RAS facilities**
- **As EIRP levels increase, OH loss model will become more important to clearing longer path interferences in the terrestrial fixed services**

Antenna RPE Smearing





- **GPS measurement error (e.g. ± 3m) leads to angular pointing error**
  - **Pointing error worst for short-distance links**
  - **±0.7° for 500m link**
- **Pointing error accommodated by smearing of the antenna RPE in interference calculations**
  - **Example exaggerated for clarity**

Automatic Transmitter Power Control (ATPC) Behavior Recommendations

- **ATPC Power Margin: 10 dB**
- **ATPC Control Range in dB: EIRP[dBW]-23**
- **ATPC Power Increase due to path fading (RSL reduction) only, not increased BER (e.g., due to interference)**
- **ATPC must be controlled through handshake with remote transmitter, to avoid instability**
- **Fading in excess of 10 dB (relative to clear air level) to be recorded for confirmation of fading event; diagnostic warning only, may be reset upon return to normal RSL**
- **If signal remains below static threshold for more than 5 minutes, transmit power must be reset to minimum and alarm triggered – transmitter power may be raised for < 1 second each 30 seconds in attempt to re-establish link**

Path Coordination

Administrative & Geographic Data

Data Field	Units / Type	Example
Site Name		High Peak
Latitude	DD-MM-SS.ss N/S	35-43-22.53 N
Longitude	DDD-MM-SS.ss E/W	081-36-29.32 W
Ground Elevation	m - AMSL	658.37
Antenna Location Detailed Description		"10 Main Street, shooting out a 12th floor window, north side"
Call Sign		WIA422
Licensee		Virginia Energy
Station Class		FXO
Link Status		Proposed
Link ID		VE00001
Registration Date		01/22/04
Registration Time	hh-mm-ss	13-04-12 UTC

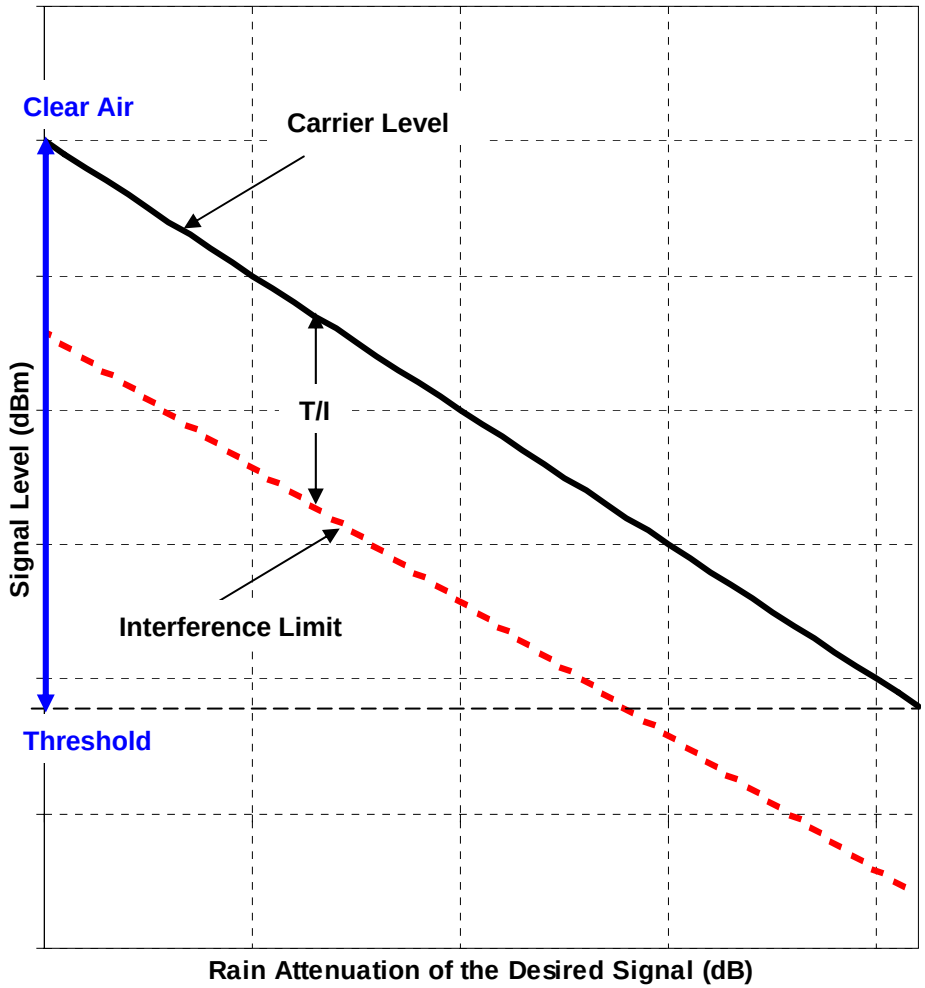
Antenna & Radio Parameters

Data Field	Units / Type	Example
Antenna Manufacturer		Andrew
Antenna Model		HP-7080A
Antenna Gain	dBi	50.0
Antenna Beamwidth	degrees	0.6
Antenna Centerline	m - AMSL	52.43
Radio Manufacturer		Cisco
Radio Model		4800 GE
Modulation		BPSK
Stability	%	0.01
Transmit Power (min / max)	dBm	5.0 / 25.0
Emission Designator		1G25D7W
Emission Bandwidth	GHz	1.25
Number of Channels		2
Channel Center Frequencies	GHz	73, 75, 83, 85
Receiver Threshold	dBm	-70.0
Fixed Loss	dB	3.0

Interference Analysis Objective

- **For each potential case of interference a threshold-to-interference ratio (T/I) shall be determined that would cause 1.0 dB of degradation to the static threshold of the protected receiver**
- **For the range of carrier power levels (C) between the clear-air (unfaded) value and the fully-faded static threshold value, in no case shall interference cause C/I to be less than T/I**
- ***Unless*** **it can be shown that the availability of the affected receiver would still be acceptable despite the interference**

Figure 4-3: Interference Objective



Analysis Steps

- **Obtain Federal Government Clearance**
  - **WCA 60+ GHz Committee would prefer process whereby path coordinator obtains “clearance” from the NTIA**
  - **FCC R&O states otherwise as of this date**
- **Perform Analysis vs. other non-Federal Links**
  - **Follow Step-by-step Process to Minimize Analysis Difficulty**
  - **Use Mitigation Options to Resolve any Remaining Cases**
    - ✓ **Blockage / OH Loss**
    - ✓ **Antenna Upgrades**
    - ✓ **Cross-polarization**
    - ✓ **Etc.**

Federal Government Coordination

- **Must Receive Federal Government Clearance to Operate**
- **Coordination with Federal Gov't Links**
  - **"Green Light" from NTIA Web Page**
  - **Pass IRAC Review for "Yellow Light"**
- **Coordination with Radio Astronomy Service**
  - **Also Expected to be Handled by NTIA/IRAC**
  - **Interference Objectives into RAS Observatories TBD by NSF**
  - **Affects 81-86 GHz Band**
  - **18 Locations in the US**
  - **Coordination Zone Radius of 25 or 150 km**

Link Analysis

- **Step 1: Radius Search**
  - **Retrieve Database Links within a Radius for Analysis**
  - **Choose Radius to Include All Links with Possible Interference**
  - **Suggest 100 km Search Radius**

Link Analysis

- **Step 2: Assume Uncorrelated Fading**
  - **Require Interference to Meet T/I Under Condition Link Carrier has Faded to Threshold**
  - **Following Example Shows Coordination Contour**
  - **Step 2 Will Eliminate Most Potential Cases Within Step 1 Search Radius**

Link Analysis

- **Step 2: Example**

Case Parameters	
Interfering Transmitter Power (dBm)	10
Interfering TX Antenna Mainbeam Gain (dBi)	50
Interfering TX EIRP (dBm)	60
Interfering TX Maximum ATPC Power Reduction (dB)	7
Interfering TX Antenna Discrimination Angle (deg)	0
Interfering TX Antenna Discrimination (dB)	0
Victim RX Bandwidth (MHz)	1000
Victim RX Noise Figure (dB)	8
Victim RX Thermal Noise Power (dBm)	-76
Interference Objective for 1 dB Threshold Degradation (dBm)	-82
Victim RX Antenna Mainbeam Gain (dBi)	50
Atmospheric Absorption Loss (dB/km)	0.4
Desired Path Length (km)	2
Desired Path Loss (dB)	136.7
Desired Transmitter Power (dBm)	10
Desired TX Antenna Mainbeam Gain (dBi)	50
Desired TX EIRP (dBm)	60
Carrier Level (dBm)	-26.68
Victim RX C/N @ 10^-6 BER (dB)	14
Victim RX T/I (dB)	20
Victim RX Threshold @ 10^-6 BER (dBm)	-62
Victim RX Fade Margin (dB)	35.32

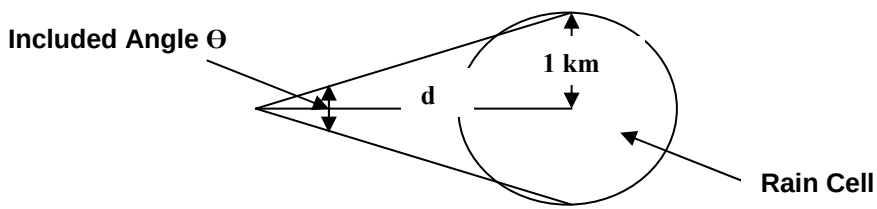
Victim RX Antenna Discrimination Angle (deg)	Victim RX Antenna Discrimination (dB)	Required Path Loss (dB)	Coordination Distance (km)	Interference Criteria
-180.0	55	137.00	1.900	I<T-(T/I)
-30.0	55	137.00	1.900	I<T-(T/I)
-29.9	50	142.00	3.200	I<T-(T/I)
-20.0	50	142.00	3.200	I<T-(T/I)
-19.9	45	147.00	5.300	I<T-(T/I)
-15.0	45	147.00	5.300	I<T-(T/I)
-14.9	40	152.00	8.200	I<T-(T/I)
-10.0	40	152.00	8.200	I<T-(T/I)
-9.9	36	156.00	11.300	I<T-(T/I)
-5.0	36	156.00	11.300	I<T-(T/I)
-4.9	0	192.00	63.800	I<T-(T/I)
0.0	0	192.00	63.800	I<T-(T/I)
4.9	0	192.00	63.800	I<T-(T/I)
5.0	36	156.00	11.300	I<T-(T/I)
9.9	36	156.00	11.300	I<T-(T/I)
10.0	40	152.00	8.200	I<T-(T/I)
14.9	40	152.00	8.200	I<T-(T/I)
15.0	45	147.00	5.300	I<T-(T/I)
19.9	45	147.00	5.300	I<T-(T/I)
20.0	50	142.00	3.200	I<T-(T/I)
29.9	50	142.00	3.200	I<T-(T/I)
30.0	55	137.00	1.900	I<T-(T/I)
180.0	55	137.00	1.900	I<T-(T/I)

Link Analysis

- **Step 3: Assume Correlated Rain Fading**
  - **Apply Rain Fading Correlation Rules-of-Thumb Based on Link Geometry**
  - **Simple C/I Checks will Demonstrate Non-Interference**

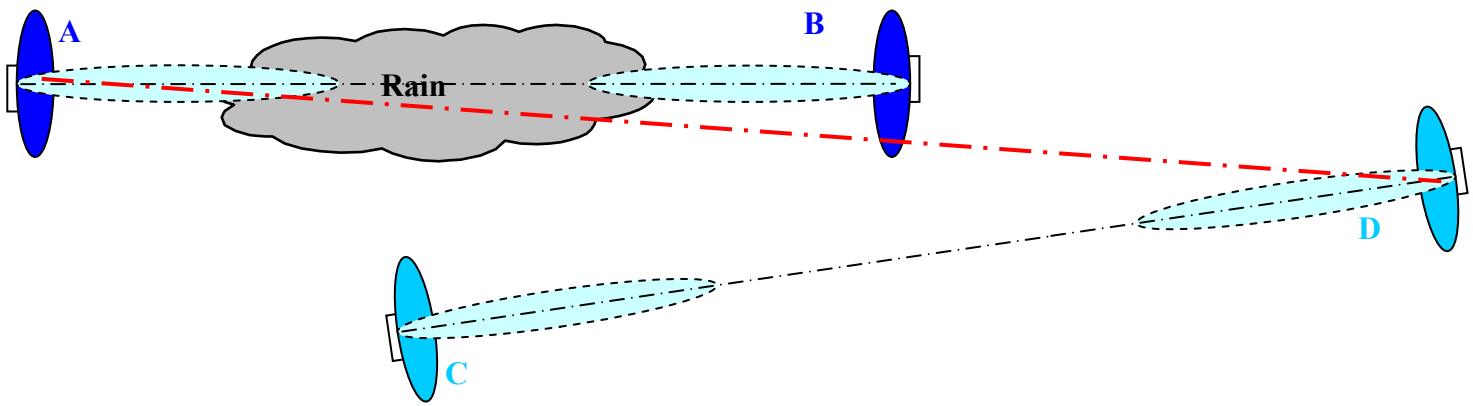
Link Analysis

- **Step 3**
  - **Rule 1: Interference Path Near Boresight of Interfering Antenna**
    - ✓ **Rain may cause ATPC power increase of interfering transmitter**
    - ✓ **The same rain cell that causes power increase of interfering transmitter also attenuates interference path**
    - ✓ **ATPC power increase offset by rain fading of interference path**
    - ✓ **Interference calculations may use low ATPC power of interfering transmitter**
  - **Rain cell diameter of 2km is centered on appropriate endpoint to define sector where rain attenuation is considered to be correlated**



Link Analysis

- **Step 3**
  - **Rule 1**
    - ✓ **ATPC power increase at A does not increase interference at D**

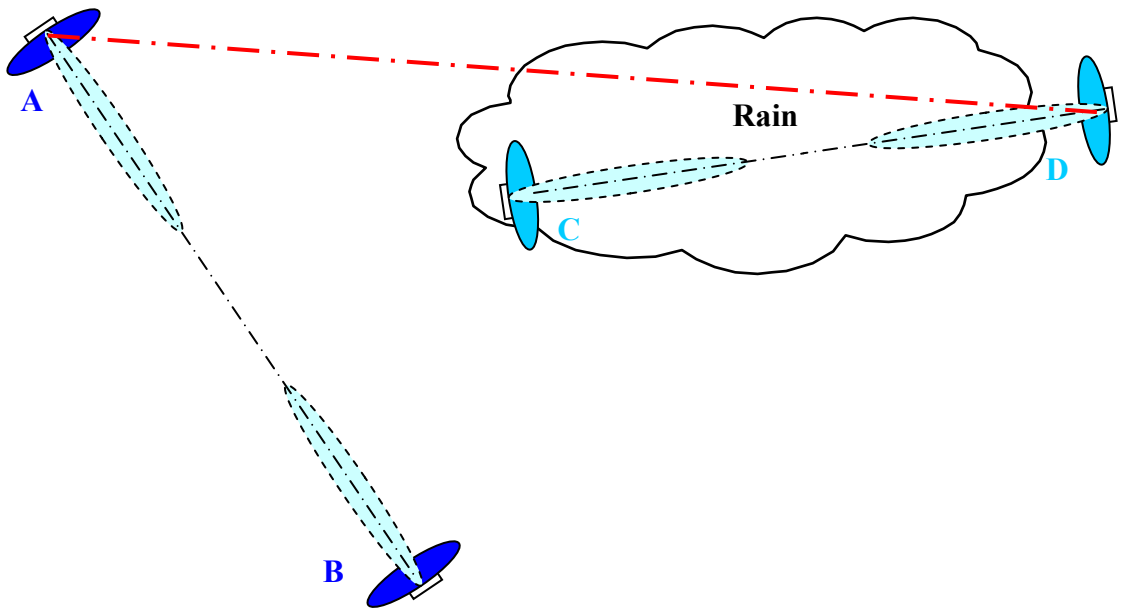


Link Analysis

- **Step 3**
  - **Rule 2: Interference Entering Victim Antenna Near Boresight Direction**
    - ✓ **Rain may cause Victim Link Carrier to Fade**
    - ✓ **The same rain cell that causes Carrier fading also attenuates interference path**
    - ✓ **C/I in clear air is worst case**
    - ✓ **Show that C/I > T/I in clear air to Resolve Case**

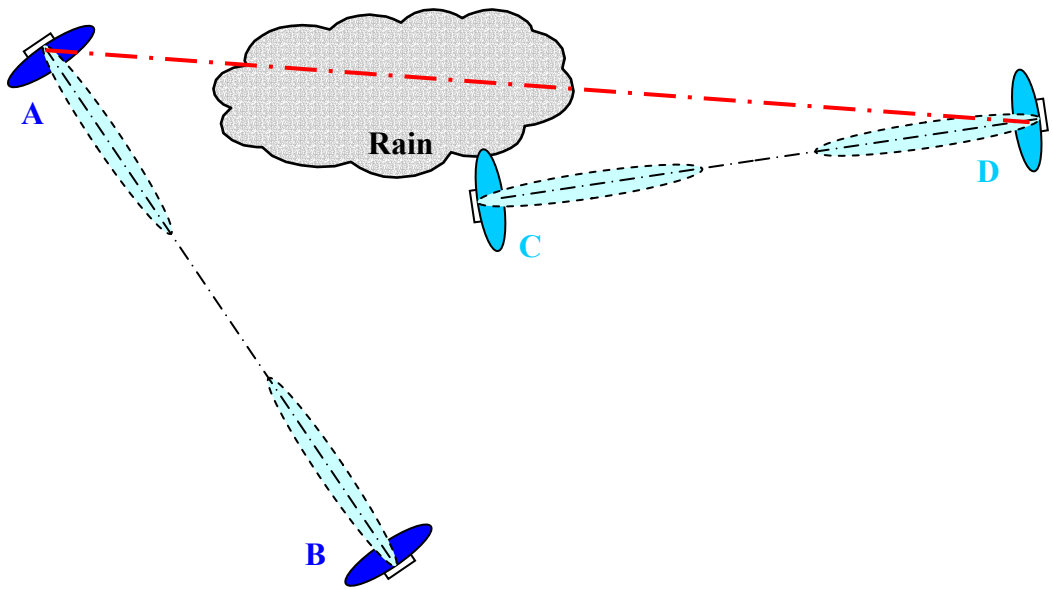
Link Analysis

- **Step 3**
  - **Rule 2**
    - ✓ **Desired signal fading equal to interference signal fading**



Link Analysis

- **Step 3**
  - **Rule 2**
    - ✓ **Desired signal fades less than interfering signal**

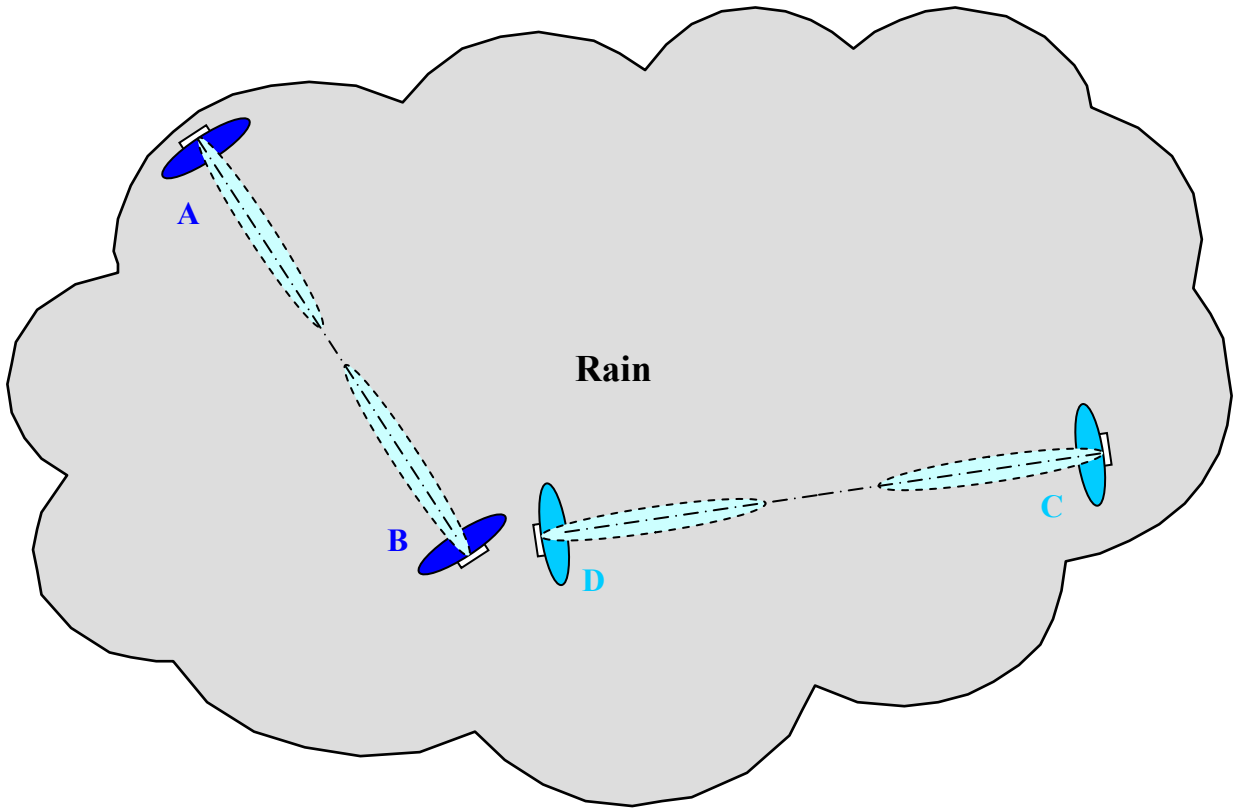


Link Analysis

- **Step 3**
  - **Rule 3: Desired and Interfering Propagation Paths within a Rain Cell**
    - ✓ **Same Fading Rate (dB/km) Affects Desired, Interfering, and Interference Paths**
    - ✓ **Can Calculate C/I at any rain rate**
    - ✓ **Show C/I > T/I for any rain rate between clear air and static threshold to resolve case**
    - ✓ **ATPC operation defines critical points to calculate C/I**

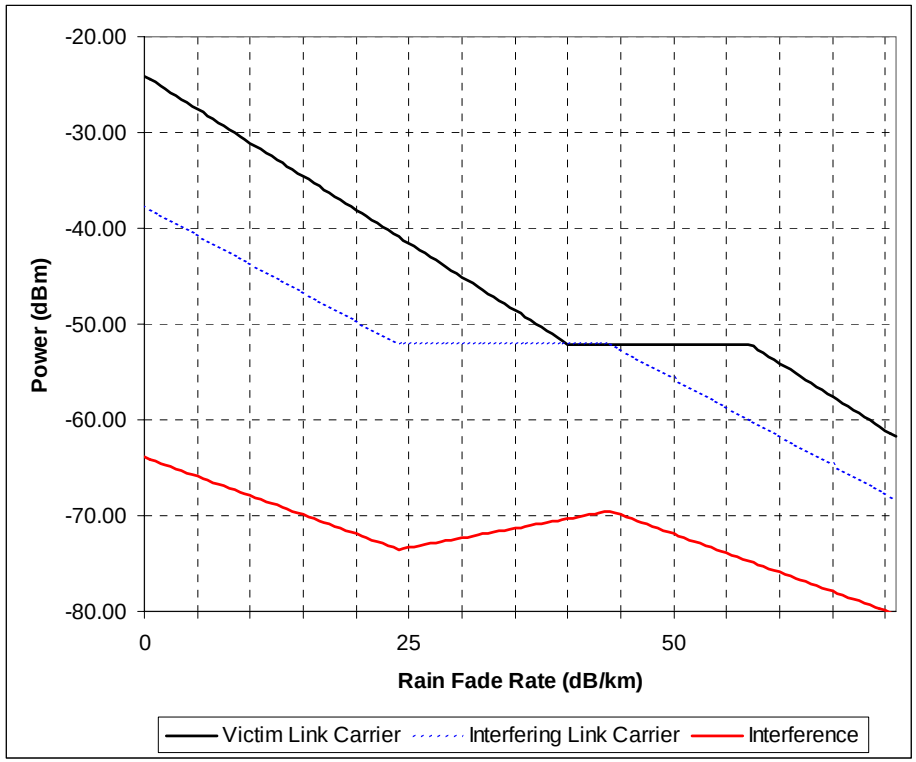
Link Analysis

- **Step 3**
  - **Rule 3**
    - ✓ **Equal rate-of-fading (dB/km) of interference and desired signals**



Link Analysis

- **Step 3**
  - **Rule 3**
    - ✓ **Equal-rate (dB/km) fading example**



Link Analysis

- **Step 4: Detailed Simulation of Rain Cells**
  - **We believe that almost all links will be cleared by the previous 3 steps**
    - ✓ **Early links will be limited in range to ~2km**
    - ✓ **Worst case rain cell diameter ~2km**
  - **Several Approaches Possible**
  - **Further Study Required**
  - **Rain cell model based on ITU-R P.452-10 (as stated earlier)**

Long Links with Small Fade Margin

- 1 dB degradation from a single interferer could impact a link with very small fade margin
- No change to the interference criteria is recommended to accommodate these links
- Use such links only at your own risk

Limiting Availability of Short Links

- **Very short links may have excessive fade margins**
- **Meeting T/I at threshold could over protect such links**
- **Recommend protecting only enough fade margin to meet 99.9999% availability**

Coordination for Co-located Radios

- **Recommend harmonized frequency plan**
  - **Matched high/low plan**
- **Need accurate antenna positions for co-located sites**
- **Additional information such as site surveys / sketches and/or measurements may be necessary**